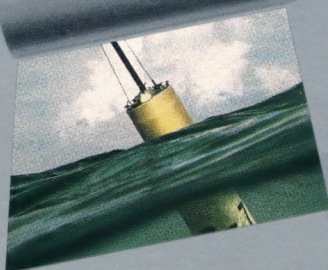


KYNARTM Piezo Film

A unique, flexible polymer film
with high piezo and pyroelectric activity.



 **PENWALT**
CHEMICALS ■ EQUIPMENT
HEALTH PRODUCTS





KYNAR™ Piezo Film—A versatile new transducer material

Piezoelectric materials, which transform a mechanical force to an electrical response and conversely, transform an electrical signal to a mechanical motion, have been known for many years. Examples are highly polar natural crystals and ceramics such as quartz and barium titanate, respectively. These materials are dense, brittle, stiff and difficult to produce in large sizes and impractical to fabricate into complex shapes. Recently, polymeric piezoelectric films have been developed. They are pliant, flexible, tough and lightweight. Of all known polymers, those based on vinylidene fluoride show the highest piezo- and pyroelectric activities. Polyvinylidene fluoride, PVDF, is the base resin used in the development of KYNAR Piezo Film by the Pennwalt Corporation. This specialty film is now available in various thicknesses for application as transducers for many industrial devices.

Molecular structure

Polyvinylidene fluoride, PVDF, is a semi-crystalline high molecular weight polymer of repeat unit ($\text{CH}_2\text{-CF}_2$) whose structure is essentially head-to-tail, i.e. $\text{-CH}_2\text{-CF}_2\text{-(CH}_2\text{-CF}_2\text{)}_n\text{-CH}_2\text{-CF}_2\text{-}$. PVDF is approximately 50% crystalline and 50% amorphous. The principal crystalline forms of PVDF are the highly polar β form and the non-polar α form shown in Figure I. High piezo response

is associated with the polar β form in which the hydrogen and fluorine atoms are arranged to give the maximum dipole moment per unit cell. The dipole moments of the crystallites are randomly oriented with respect to each other unless the film is electrically polarized. Pennwalt produces KYNAR Piezo Film by means of carefully controlled processing steps which include mechanical orientation and treatment in an intense

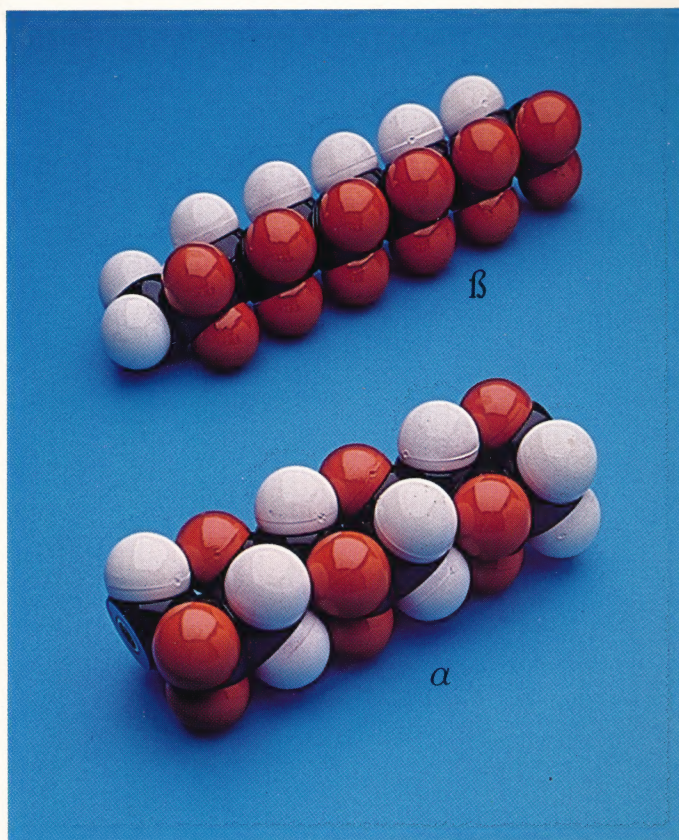


Figure I

electric field. The resulting product containing predominantly oriented β form crystallites exhibits a large net polarization. It is this net polarization that gives the film its high piezoelectric and pyroelectric activities.

KYNAR Piezo Film—Unique Characteristics

The basic characteristics that make KYNAR Piezo Film unique and useful in many electronic transducer applications are:

- ☐ High pyroelectric sensitivity.
- ☐ High piezoelectric sensitivity in planar, thickness, and hydrostatic modes.
- ☐ Good fidelity throughout a broad range of frequencies.
- ☐ Low mechanical and acoustic impedance.
- ☐ High dielectric strength—much higher than ceramics.
- ☐ Resistance to moisture and high humidity.
- ☐ Tough, flexible and lightweight.
- ☐ Available as thin film—readily cut and shaped to form complex configurations.
- ☐ Easily laminated to produce bimorph and multimorph elements which multiply transducer response.
- ☐ Not subject to breakage and loss of dipolar properties when subjected to mechanical impact.

Properties of KYNAR Piezo Film and other Materials (in Length Expansion Mode)

Materials	Cut	Density	Elastic Stiffness	Relative Dielectric Constant	Piezoelectric Constant					Coupling Factor	Acoustic Impedance
					d m/V (coul/N)	e N/V m ₂ (coul/m ²)	g V m/N	h V/m	k calculated		
		ρ kg/m ³	c N/m ²	ϵ/ϵ_0	(10 ⁻¹²)	(10 ⁻²)	(10 ⁻³)	(10 ⁷)	(%)		(10 ⁶)
Quartz	X	2.65	77.2	4.5	2	15	50	380	10		14.3
Rochesalt	45°X	1.77	17.7	350	275	490	90	160	73		5.6
PZT	Z	7.5	83.3	1200	110	920	10	90	30		30
BaT ₂ O ₃	Z	5.7	110	1700	78	860	5.2	60	21		30
Kynar Film	Z	1.78	3	12	23	6.9	200	65	12		2.5

KYNAR Piezo Film Properties

The level of piezo activity in KYNAR Piezo Film may be readily determined by standard test methods.

The coordinate system showing the piezo constants, d_{31} , d_{32} , and d_{33} are illustrated in Figure II. The first index (subscript 3 on d_{31}) specifies the electrical (polar) axis. The second index (subscript 1 on d_{31}) indicates the mechanical (stress or strain) axis. These constants along with typical basic properties of KYNAR Piezo Film are listed in Table I.

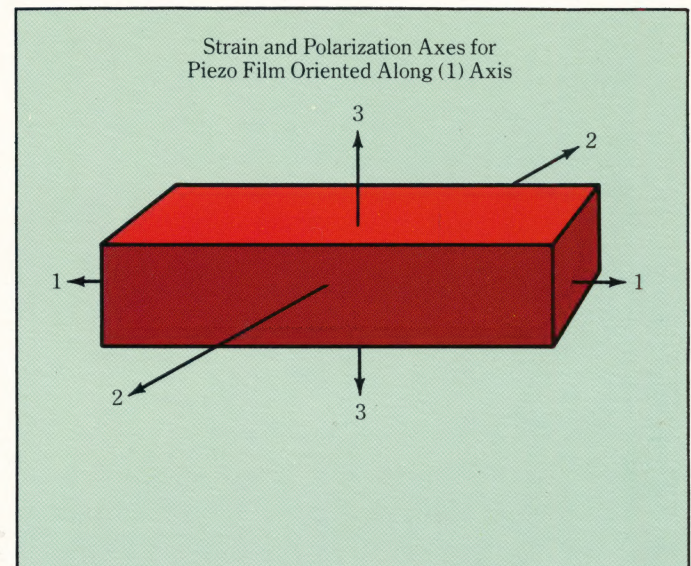


Figure II

The changes in several properties with frequency and temperatures are shown in Figures III through VI on page 3. The thermal stability of piezo activity as shown in Figure III demonstrates that after an initial decay, piezo activity becomes very stable. Most of the decay below 100°C is caused by thermally induced mechanical relaxation and is not related to depolarization effects.



Figure IV illustrates the dependence of dielectric permittivity and dissipation factor on frequency at ambient temperature. As a result of its relatively low dielectric permittivity (100 fold less than piezo ceramics), the g-constants (voltage output coefficients) of PVDF are significantly greater than those of ceramics. Thus PVDF can be made into very responsive sensors of mechanical signals.

The relationships between electrical impedance and frequency for various thicknesses of KYNAR Piezo Film, 100 sq. cm in area, are shown in Figure V. These data are important for matching film impedance to associated components in the circuit. The influence of frequency on the electro-mechanical coupling factor " k_{31} " is shown in Figure VI. Although k_{31} and therefore the efficiency of energy transfer is low compared to ceramic transducers, KYNAR Piezo Film elements can be used at much higher fields than ceramics which result in desirable mechanical deflections. For example, because its dielectric strength is 70 times that of PZT ceramics, the maximum input capability for electrical energy of PVDF is 40 times greater and the corresponding output of mechanical energy is 5 times greater.

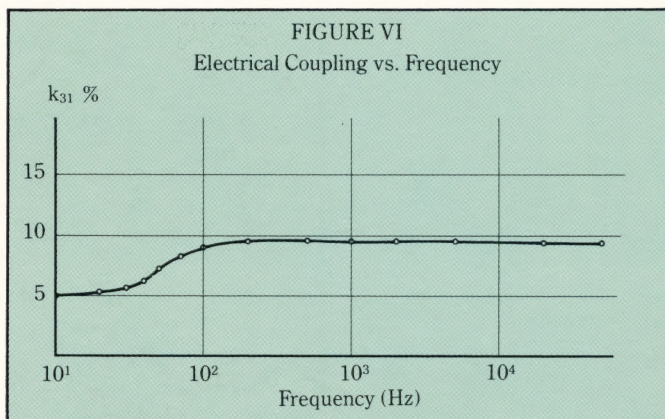
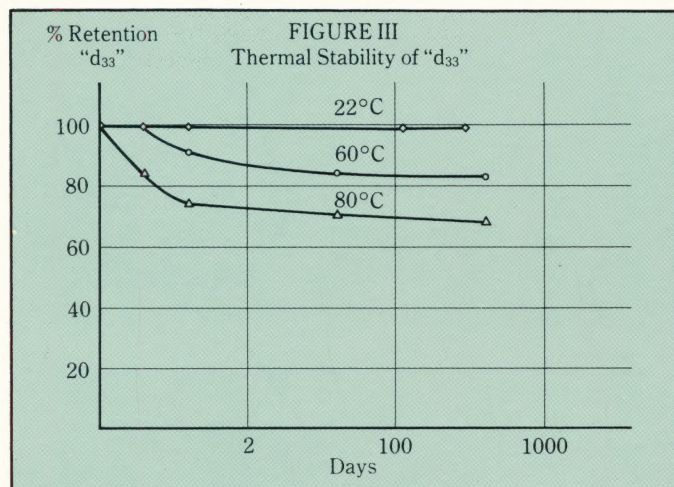
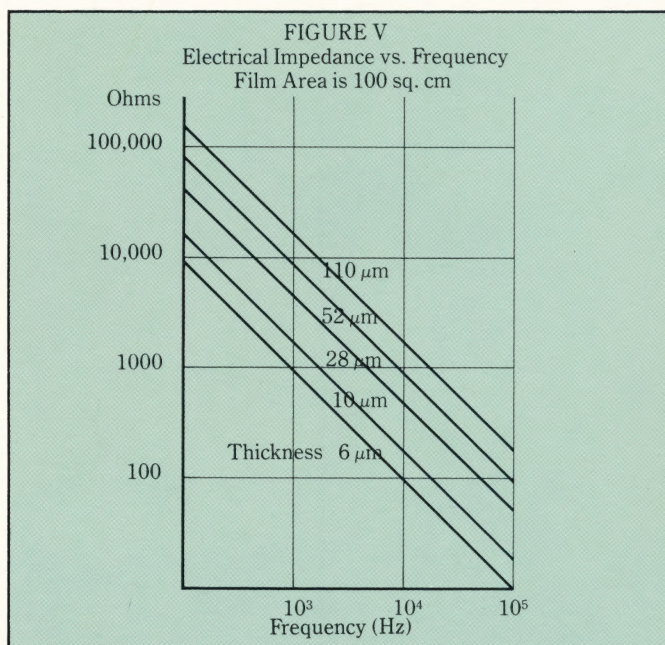
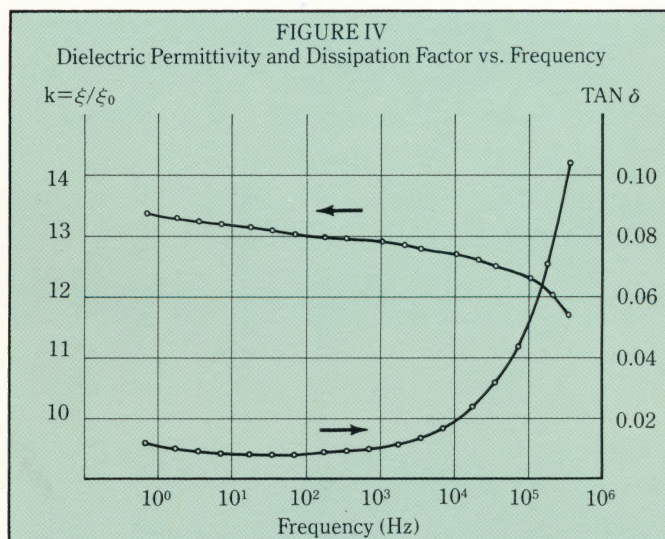


TABLE I
TYPICAL PROPERTIES OF KYNAR PIEZO FILM

PROPERTY		VALUE	UNITS
Thickness		6-125	μm
Surface Conductivity of Metallized Film	Al	1-4	$\Omega \square^{-1}$
	Ni	10-25	
Static Piezoelectric Strain Constant	d_{31}	20-25	$\text{pC N}^{-1} (\text{pm V}^{-1})$
	d_{33}^*	20-22	
Static Voltage Output Coefficient	g_{31}	0.230	Vm N^{-1}
	g_{33}	0.210	
Electromechanical Coupling Factor	k_{31}	9-15	% at 100 Hz
Pyroelectric Coefficient	p	23-27	$\mu\text{C m}^{-2} \text{ } ^\circ\text{K}^{-1}$
Shrinkage in Machine Direction	60°C	2	% after annealing 100 hrs.
	80°C	4	
Relative Dielectric Permittivity	ϵ / ϵ_0	12 ± 1	at 1000 Hz
Dielectric Loss Factor	$\tan \delta$	0.015-0.02	at 1000 Hz
Volume Resistivity	ρ	10^{13}	Ωm
Tensile Strength at Yield	MD**	—	10^6Nm^{-2}
	TD**	40-110	
Tensile Strength at Break	MD	160-330	10^6Nm^{-2}
	TD	30-55	
Elongation at Break	MD	25-40	%
	TD	380-430	
Young's Modulus of Elasticity = Elastic Stiffness = c^E	MD	1.5-3	10^9Nm^{-2}
	TD	1.1-2.4	
Melting Point		165-180	$^\circ\text{C}$
Flammability, LOI		44	%O ₂
Thermal Conductivity		0.13	$\text{W m}^{-1} \text{ } ^\circ\text{K}^{-1}$
Specific Heat		2.5	$\text{MJ m}^{-3} \text{ } ^\circ\text{K}^{-1}$
Density		1.8	g (cm)^{-3}
Thermal Expansion Coefficient		1.4	$10^{-4} \text{ } ^\circ\text{K}^{-1}$
Sound Velocity***		1.5-2.2	kms^{-1}

*measurements were made in hydraulic press (e_{33}/c_{33}) **MD = Machine Direction (1) and TD = Transverse Direction to film orientation (2)

***longitudinal and thickness modes.



Audio Applications: as the active element in microphones and stereo pickups, and in speakers and headphones, KYNAR Piezo Film affords lightweight, compact design, easy formability to desired geometry, and high fidelity response. It has low acoustic and mechanical impedance and is well-suited for the design of noise-cancelling microphones.

Switching Components: as patterned switch elements in "finger-pressure touch action" keyboards and key pads for typewriters, telephones and computer terminals, KYNAR Piezo Film has virtually unlimited

life. Such switches have been tested for millions of operations without failure. These elements are also useful in impact detectors, coin sensing systems, and actuators for explosives.

Instrumentation: as sensors for instruments used to monitor vibration, deformation, acceleration, pressure, fluid flow, and seismic pulses. In medical applications as sensors for monitoring heartbeat, breathing, and blood flow.

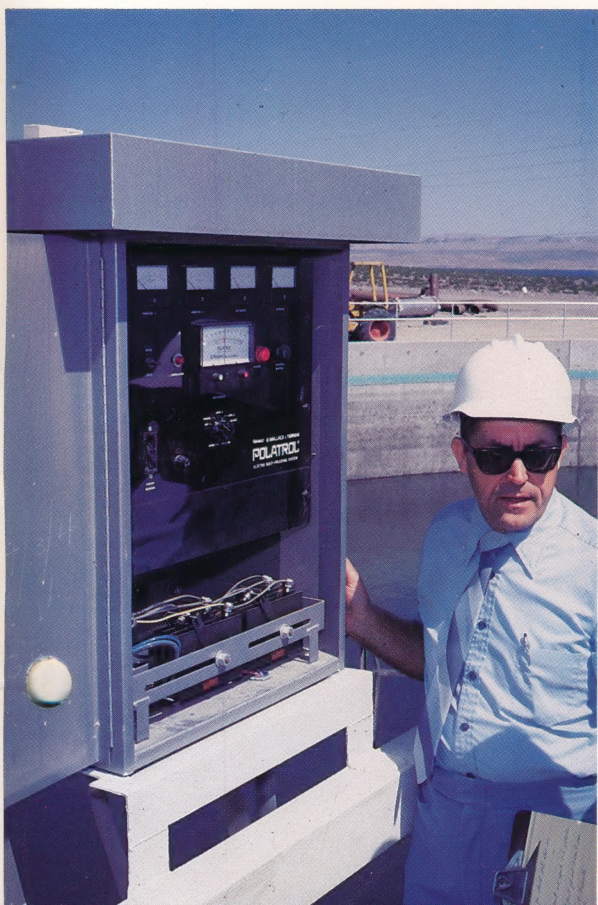


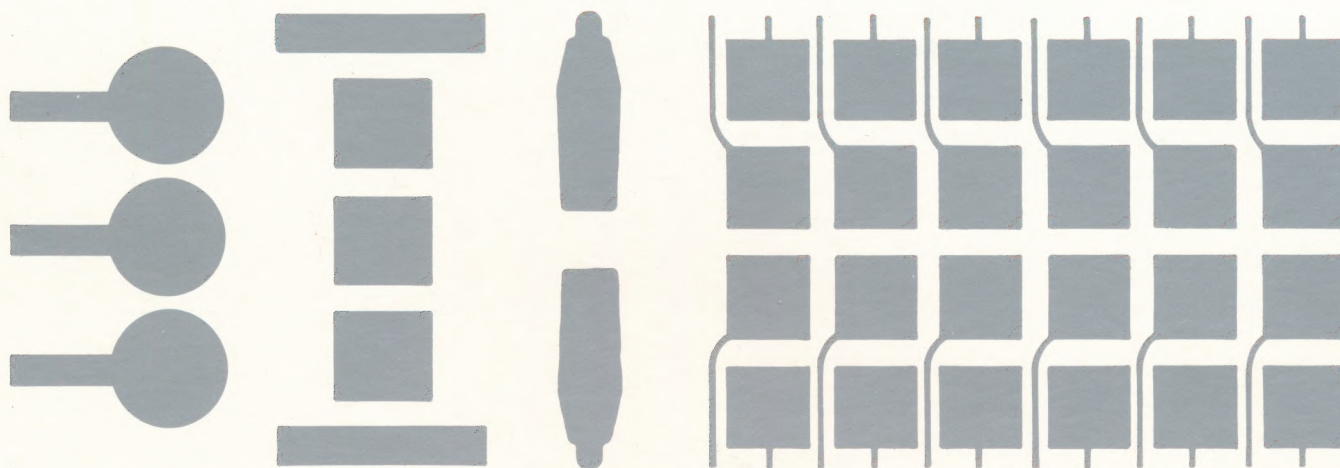
Ultrasonic Sensing: because its acoustic impedance is close to that of water and body tissue, KYNAR Piezo Film is an excellent choice for applications in medical imaging equipment. It is also being evaluated for non-destructive testing instruments and for range-finding systems.

Underwater Sound Detection: as large, flexible elements for hydrophones, sonobuoys and towed arrays used for submarine detection and oil exploration.

Heat sensors: because of its excellent electrical response to incident infra-red radiation, KYNAR Piezo Film is used in intrusion and fire alarms, heat scanners, and pyroelectric energy control systems. It also shows promise for applications in infra-red imaging equipment and electrostatic copying.

Flexure-mode Transducers: as bimorph constructions in motion displays, "motorless" fans, pumps, shutters and position sensors.





Film Thickness

KYNAR Piezo Film can be supplied in a range of thicknesses, from a few microns to several hundred microns.

Thin films are recommended where a high efficiency of conversion of electrical signals into mechanical motion is needed as in headphones, speakers, and bimorph designs utilizing the d_{31} mode. Thin film is also preferred for pyroelectric applications where rapid response is required.

Thick films are recommended in applications where a voltage is generated by thickness change or hydrostatic pressure. An example is sonar transducers for underwater sound detection.

Bimorph Elements

KYNAR Piezo Film is readily laminated into bimorph stacks, which increase the mechanical motion generated in cantilever devices. Either series or parallel arrangements can be used. This technique is also applicable to sensors as a means of multiplying electrical output.

KYNAR Piezo Film is available in the following forms and styles:

- ☐ Continuous rolls
- ☐ Sheets
- ☐ Various thicknesses
- ☐ Unmetallized and metallized surfaces
- ☐ Custom-metallized patterns (above)
- ☐ Specialized elements to customer specifications

Pennwalt is supplying KYNAR Piezo Film and customized elements to companies throughout the world for use in commercially available products as well as for many new products under development.

For further information and technical service contact the KYNAR Piezo Group, Pennwalt Corporation, 900 First Avenue, P.O. Box C, King of Prussia, PA 19406-0018, (215) 337-6750 or call toll free (800) 345-8112; in Pennsylvania, (800) 662-2444.

KYNAR™ PIEZO FILM

KYNAR™ Piezo Film brings you a combination of characteristics never before available: a flexible film with the highest piezoelectric and pyroelectric activity of any polymer, available in large sheet sizes, easy to form into complex shapes, and free of the limitations of



fragile, brittle and hard-to-fabricate crystals and ceramics.

No wonder KYNAR Piezo Film is being used successfully in applications such as these:

Audio applications. Microphones, headphones, speakers. KYNAR Piezo Film has low acoustic and mechanical impedance, and frequency response from DC to GHz.

Switches. Keyboards and keypads for typewriters, telephones, computer terminals. High resistance to impact and fatigue means film won't shatter or deform over millions of touch operations.

Industrial and Medical Instrumentation. As sensors for pressure, vibration, strain and fluid flow. Medical equipment: for ultrasonic imaging, for monitoring of

heartbeat, and measuring respiration and blood flow.

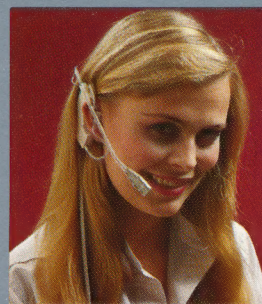
Underwater Sound Detection.

As elements for hydrophones and sonobuoys. Acoustic impedance is close to that of water.

Heat sensors. For fire and intrusion alarms and for energy control systems.

Motion Devices. For displays, shutters, position sensors, "motorless" fans.

KYNAR Piezo Film is available in commercial quantities, in a range of thicknesses, sizes, and types of metallization



to meet designers' needs. For technical data, price and delivery information, and assistance in customized applications, call toll-free (800) 345-8112, in Penn-

sylvania, (800) 662-2444, or write to: KYNAR Piezo Group, Pennwalt Corporation, 900 First Avenue, P.O. Box C, King of Prussia, PA 19406-0018.

It's sparking a transducer revolution.

 **PENNWALT**
CHEMICALS ■ EQUIPMENT
HEALTH PRODUCTS